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ARSENICAL INJURY ON THE PEACH



Peach branches showing cankers and injured areas in the crotches where the arsenical toxin was concentrated.

THE AGRICULTURAL EXPERIMENT STATION
OF THE
NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING
AND
NORTH CAROLINA DEPARTMENT OF AGRICULTURE, CO-OPERATING
R. Y. WINTERS, Director
STATE COLLEGE STATION
RALEIGH



ARSENICAL INJURY ON THE PEACH

R. FRANK POOLE, *Plant Pathologist*

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Arsenical injury has become a serious detrimental factor in growing the peach crop. Heavy damage to foliage, twig and fruit has become so important that growers are seriously thinking of omitting lead arsenate from sprays. Until another substitute for arsenate of lead is found, however, any such procedure would be hazardous to the production of a quality crop of peaches. In some instances the grower confuses arsenical injury with the equally important bacterial spot because of certain resemblances of the two diseases in the early stages of development. The two problems often occur simultaneously and frequently are distinguished with difficulty. During the past six years these two diseases were studied in areas where both cause significant losses annually. The results of these studies, while not complete are sufficiently assuring in offering such definite control measures as to warrant certain specific recommendations for reducing arsenical injury.

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IMPORTANCE OF ARSENICAL INJURY

At one time or another arsenical injury has been reported from every important center of the peach growing industry. It is frequently reported as severe in orchards along the Atlantic Seaboard from Georgia to New Jersey. At times, it has also caused serious injury in the central states. In this State premature defoliation early in the season has frequently resulted in losses ranging from 5 to 35 per cent, since much of the fruit on defoliated trees failed to reach a desirable marketable size or was marked by the arsenical injury. The destruction of fruit buds has been heavy and contributory to low yields in some seasons. The loss of fruit has caused most concern since the injury frequently occurs on the peach immediately preceding harvest and sometimes amounts to 50 per cent of the crop in some orchards. The shape of the tree is sometimes affected, since the limbs with split crocks frequently break off during wind storms in later years.

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Symptoms of Arsenical Injury

Injury on the leaf is manifest as a circular spot and ragged dead tissue along the margins (Plate 1). The tissues in the injured spots at first appear lighter because of loss of green pigment and become water soaked as contrasted with the healthy green tissues. The injured cells die suddenly and become brown as they dry out. Later the dead tissues are blown out leaving shot hole markings on any part of the leaf and ragged edges. The final result is sometimes not unlike the injury caused by wind (13). The injury frequently advances until all parts of the leaf are affected and the tissues turn yellow and finally dark brown. This injury is often seen from one to six weeks following the first application of arsenate of lead. It is sometimes seen a few days after the arsenate is applied. The late appearance is said to be due to the gradual transformation of the insol-

uble arsenate of lead to "water soluble arsenic" (11-15), "dilead arsenic" (9), arsenic trioxide (17), and tricalcium arsenate (10). On the leaf, arsenical injury is sometimes confused with the bacterial spot which is angular and much smaller and with the purple and brown physiological spot resulting from weakened and deficiency conditions brought about by diseased roots. The purple and brown spot caused by the latter condition is by far the most confusing. However, the effects are definitely unlike in that the tissues remain partly alive sometime throughout the season and defoliation is much less common than has been observed following arsenical injury.

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Injury on the new and one-year old bud wood is of a dark brown necrotic type becoming most prominent at the base of the bud where the tissues are killed sometimes to a depth of one-sixteenth of an inch. The twig is sometimes, but not always, killed as a result of severe bud injury. On severely cankered twigs defoliation even in the autumn is premature and the leaves are often small and mixed with red and yellow colors as compared with the healthy green leaves. Complete defoliation of new wood frequently results in dessication and death of the twig (Fig. 1). Young bud wood on which severe cankering occurs, but not complete defoliation, frequently recovers sufficiently to regain and maintain a productive state. The fruit bud is sometimes destroyed while the leaf bud may escape serious damage. Hypertrophic cankers with roughened bark and split cracks are commonly produced on the larger twigs. This injury does not stop immediately but continues deeper into the wood even weeks after the arsenical injury begins. The dead tissues dry, crack and remain conspicuously in the tree for several years. Their location is invariably at the nodes, and may be fairly accurately distinguished from the larger and less regular cankers and injuries caused by *Bacterium pruni*, the cause of the bacterial spot or bacteriosis, which develop between the nodes with regularity. Gum exudations are frequently observed on the old cankers during wet weather. These excretions, however, often result from any sort of injury to the wood.

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Transformation of the normal color pigments to pink and later dark brown effects are observed on the fruit. The tissue on green fruit at first is apparently not injured, even for some time following the development of considerable pink color. It is definitely shown that the injury on fruit is continuous and may not cease until all tissue is destroyed to the stone on the side that is injured. As the toxic chemical advances in wood and fruit the color of the tissues becomes dark brown and cracked after drying. Saprophytic organisms invade the injured tissues and produce a variety of rots on the fruit before or soon after it is harvested. The peach may become injured on any part of its surface, but most of the injury occurs on the parts exposed to the direct rays of the sun during midday and early afternoon. It is especially prominent on those parts nearest to the stem.

ARSENICAL INJURY ON DIFFERENT VARIETIES

Arsenical injury has been observed on all varieties grown commercially including Early Rose, Red Bird, Hiley Belle, Georgia Belle, Elberta, Hale and Augbert and many minor and seedling varieties. The foliage, buds and twigs of Early Rose, Red Bird, Hiley Belle and Georgia Belle varieties were injured more severely by the first two applications than were the

Elberta and Hale varieties. The development of large cankers and split crocks are invariably most pronounced on the early varieties. Leaf injury persists and gradually becomes more severe as the season advances. Sometimes the foliage becomes severely injured and, at the end of the season throughout the tree, there is a prominent appearance of the brown and ragged leaves. Defoliation resulting from arsenate injury is frequently so severe on the Hiley Belle variety that the fruit fails to develop to normal size. This effect is more important on early than on late varieties. All varieties subject to severe injury and to defoliation continue to develop new foliage and twigs, which tend to offset losses in sizes of fruit and permanent injury to the tree. Losses resulting from scarred fruit are generally most severe on the late varieties including Elberta, Hale, and Augbert. Hurt (7) observed injury to be more severe on J. H. Hale than on the Elberta and Georgia Belle, which were not severely injured. He made no reference as to whether or not this applied to the tree as a whole or to fruit.

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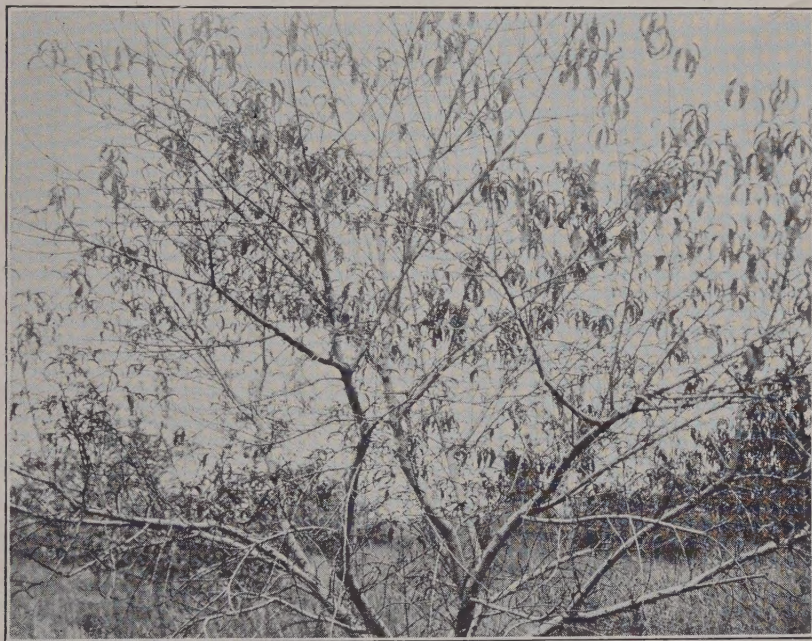
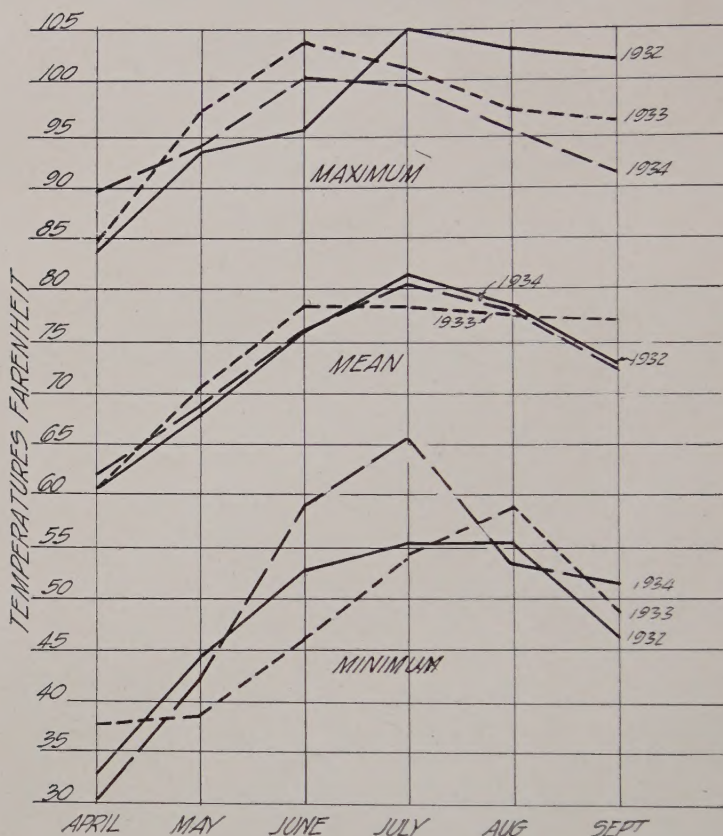


FIG. 1. Tree showing heavy defoliation as result of arsenical injury and naked twigs throughout the tree, many of which died before the end of the growing season and during the autumn.

In the orchards of the Pinehurst Peach Company at West End, an early light yellow strain of the Elberta variety has shown continuous immunization to arsenical injury even in seasons when the common Elberta growing in adjacent rows and receiving spray from the same mixture became partly defoliated and the buds became severely cankered. It is not understood what factors are conducive to the resistance of this varietal strain to arsenical damage. Swindell and Morris (17) also indicate that individual plants of the same species and variety vary in susceptibility to arsenical injury.

**MAXIMUM-MINIMUM AND MEAN TEMPERATURES
AN AVERAGE OF
ROCKINGHAM-PINEHURST AND SOUTHERN PINES STATIONS
DURING THE GROWING SEASON**



THE RELATION OF GROWTH CHARACTERS TO INJURY

Leaves and twigs of trees in a very high state of growth are most susceptible to arsenical injury, but the later and actual effects are not as prominently displayed as on weakened trees. This may be accounted for by the fact that new twig and foliage growth is quickly produced on vigorous trees, which also tend to hold injured foliage more persistently. Trees with roots infected with such organisms as *Armillaria mellea*, *Bacterium tumefaciens*, and *Heterodera radicola* are frequently badly stunted in growth resulting in smaller amounts of new foliage as compared with the larger amounts prominently developed on healthy trees. Any injury on these weakened trees is therefore more conspicuous than it is on healthy trees. However, the nature of the growth on trees weakened by root rots

caused by these organisms tend to develop a definite hardness that is certainly contributory to resistance, since it is clearly shown that both newly formed foliage and twigs appear to be more susceptible to injury than older leaves and woods on the same tree. Fruit injury is, however, much more severe on weakened than healthy trees. The weakened trees frequently show as much as 60 per cent of the fruit injured to an unmarketable condition. Bennett (1) observed arsenical injury to be worse after midsummer and on weakened trees. Haenseler (5) also found injury worse on weak trees. xxii 32
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RELATION OF SEASONAL CONDITIONS TO ARSENICAL INJURY

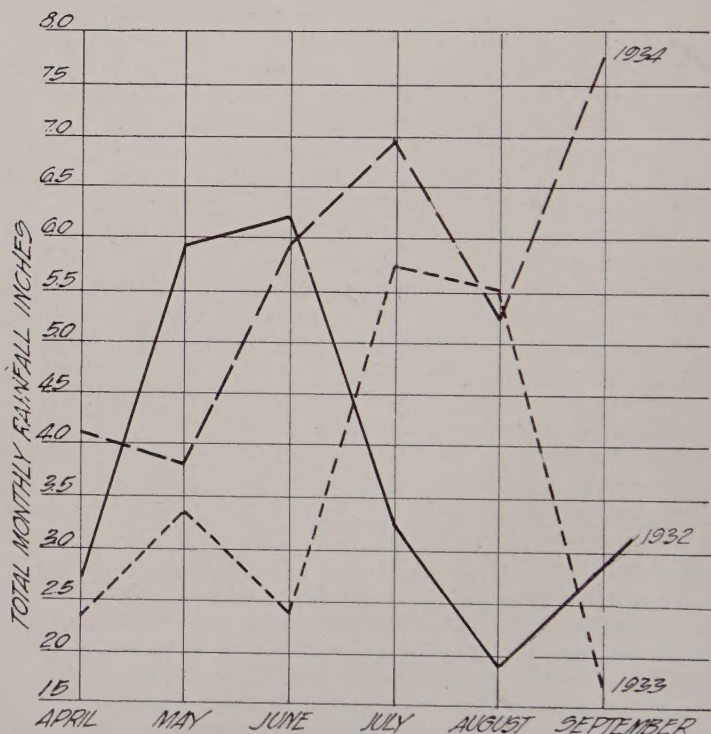
The climatological data collected by the United States Weather Bureau at Rockingham, Pinehurst, Southern Pines and a substation at Hamlet (2) offers interesting and significant facts on weather conditions throughout the growing season of April through September and make it possible for a correlation of their relations to occurrence of diseases. These stations are located at strategic points in the principal areas where the arsenical injury has been studied. The maximum and minimum temperatures for the three principal stations in any season were mostly uniform. The differences in either extreme at the four stations for any year is rarely greater than five degrees, and often checks within two and three degrees. Over a period of three years, 1932, 1933, and 1934, the mean temperatures averaged for the three stations were not significantly different (Fig. 2). The minimum temperatures were higher in 1934 during June and July than in the same months of 1932 and 1933. The variation was 13 and 6 degrees higher than the June temperatures of 1933 and 1932 respectively. The variation in July was 11.6 and 10.3 degrees. The maximum temperatures of the 1932 season were slightly lower than of the other two seasons through June but remained higher during July, August, and September.

It is true that the maximum and minimum temperatures do not fully cover all facts pertinent to a full discussion of this problem. However, the arsenical injury was sometimes severe in April when the temperatures were lowest and again in June and July when they were highest. At this time there seems to be very little if any effect of natural field temperatures on the occurrence of injury. Swingle and Morris (17) under laboratory conditions observed an increase in injury severeness as the temperatures increased from 59 degrees Fahrenheit. However, they did not consider the temperatures under field conditions of importance in developing arsenical injury.

On the other hand, moisture plays an important part in arsenical injury. The injury is decidedly worse in wet seasons. Swingle and Morris (17) after studying the arsenate compounds over a period of years, stated: "that humidity is one of the great contributing factors in arsenical spray injury is one of the most striking facts constantly in evidence throughout this investigation." Woodworth and Colby (18) found that leaves kept perfectly dry are not subject to injury by arsenates but may become severely injured under conditions of high humidity. McConnell and Smith (15) observed the occurrence of fogs to influence greater arsenical injury. Fernold and Browne (3) state that: "the injury to such tender foliage as that of peach and plum is influenced by both temperature and humidity."

In 1932 and 1933, relatively dry seasons, the injury occurring throughout the season was less pronounced than it was in the wet season of 1934 when it occurred continuously throughout the season. It occurred in May and June during 1932 when the rainfall was around 6.0 inches for both months, and in July during 1933 just previous to the harvest period when the rainfall was above 5.5 inches for the month. It was of minor importance during the low rainfall periods in these years. The average rainfall of the three stations during the growing period for the three seasons is shown in the graph (Fig. 3). It seems probable that the removal of the protective lime during rainfall and the subsequent transformations of arsenicals to soluble arsenic compounds is a factor to be considered in developing methods of control.

AVERAGE RAINFALL OF THE ROCKINGHAM-PINEHURST AND SOUTHERN PINES STATIONS DURING THE GROWING SEASON



SOURCES OF ARSENATE OF LEAD USED

The arsenate of lead in powdered form used in this State is processed by various chemical companies. The damage produced by all of these

materials has been variable but consistently similar in severeness. In certain states as much as one and one-half pounds of arsenate of lead in fifty gallons of water or spray solution is used. However, in this State, for ten years, this material has been used at the rate of one pound in fifty gallons of water. The suggestions of Snapp (16) have been followed generally. Applications have varied in number from three to four during the growing season. The first application is given when three-fourths of the petals have fallen, the second when the small peaches are exposed and the shucks are shedding, and the third about 10 weeks after petal fall and approximately four weeks prior to harvest. The arsenate of lead is sometimes made into a paste before it is added to the lime solution in the tank. More often than not the powdered arsenate of lead already weighed out in the proper amount for 200 gallons of spray solution is poured directly from the bag into the solution during agitation. Lime at the rate of five pounds in fifty gallons of water has been customarily used along with one pound of arsenate of lead in fifty gallons of water. Sometimes as much as ten pounds of lime has been used, but rarely less than five pounds. Applications of this spray have been made with the best of spray equipment including both the smaller spray and the larger high pressure spray rigs.

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THE RELATION OF DIFFERENT LIMES TO THE DEVELOPMENT OF ARSENICAL INJURY

The coarse hydrated limes were used extensively in preparing spray solutions in this State prior to 1932 (12). Even when these limes were used generally at the rate of 5 pounds with one pound of arsenate of lead, in 50 gallons of water, severe injury occurred in wet seasons. A very large percentage of the contents of these limes failed to suspend but sank to the bottom of the tank and had to be removed after each tank of spray was applied because the heavy coarse particles were prevailing sources of trouble in clogging the disks. Tests with the finishing hydrated and chemical hydrated limes meshing from two to three hundred indicated their superiority to the coarser limes both as to reduction in arsenical injury and spraying qualities of the solution. They reduced injury from 25 to 50 per cent as compared with the coarser limes. However, some injury occurred even when 5 pounds of these limes were used with the one pound of arsenate of lead. Further tests with 10, 20, and 50 pounds of lime indicated that the injury was reduced as the lime was increased. There was neither lime nor arsenical injury when 50 pounds of lime was added to fifty gallons of water and five gallons applied to each tree on four different occasions throughout the season. Increasing the lime involved greater cost and also objectionable deposits which were not removed by harvest in dry seasons. Mogendorff (10) found that injury occurred regardless of the sort of hydrated lime used and concluded that, theoretically, gypsum is a better material than hydrated lime to use in combination with lead arsenate. However, this inert chemical has not given material reduction of arsenical injury in tests conducted in this State. He showed that when the lead arsenate was combined with hydrated or freshly slacked lime it was found to be decomposed and converted into basic lead arsenate and very insoluble basic calcium arsenate and basic calcium arsenate will be transformed to less basic compounds and then to tricalcium arsenate, which is soluble enough to cause injury. He advised against the use of limes that

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have been exposed to the air for a long time. Hurt (7) found that hydrated limes were almost worthless for preventing arsenical injury in wet seasons. Haenseler (5) stated, "in mixtures containing sulfur, lime and arsenate of lead, injury occurred only when the lime was appreciably reduced, or the arsenate of lead increased over the amounts generally recommended."

ARSENICAL EFFECTS WHEN ARSENATE OF LEAD IS APPLIED WITH FUNGICIDES

It is generally well known that when Bordeaux mixture is used with arsenate of lead it acts as a suppresser of arsenical injury on plants tolerant of copper mixtures. This may also be safely said of the insoluble copper compounds such as copper phosphate and ammonium copper silicate, which were safely used on peaches during June and July, but not before these months in this State. Temperature probably is responsible for this behavior, which is not yet fully determined. Potassium permanganate, emulsified phenol and emulsified cresol stimulated arsenical injury (12). Patten and O'Meara (11) showed that carbon dioxide in aqueous solution resulted in more soluble arsenic. Smith (15) showed that excretions from



FIG. 4. Tree sprayed throughout season with 4 pounds of zinc sulfate, 5 pounds of lime, and one pound of arsenate of lead in 50 gallons of water, showing absence of arsenical injury, full foliage and normal growth of new wood.

leaves increased the water soluble arsenate content. Haywood (6) indicated a relation of carbonates and chlorides to the development of soluble arsenic compounds. Swingle and Morris (17) found that lime sulfur increased arsenical injury. Haenseler (5) found that self-boiled lime sulfur, 8-8-50 with $1\frac{1}{2}$ pounds of arsenate of lead, caused no injury, while dry-mix, 8-4 $\frac{1}{2}$ -50, with $1\frac{1}{2}$ pounds of arsenate of lead, caused injury and

sprays applied early in the season caused more injury than those applied later. Ginsburg (4) indicated that soaps of strong bases form more soluble arsenic than soaps of weak bases and that potash fish oil soap stimulated injury. Roberts and Pierce (14) who developed the zinc-lime spray for peaches, observed less arsenical injury where arsenate of lead was used with the zinc-lime spray than when used with sulfur and lime. Hurt (7) observed almost complete control of arsenical injury where zinc-lime was used. He suggested that the zinc hydrate which is formed by chemical reaction between the hydrated lime and zinc sulfate, takes up the water soluble arsenate in the form of an insoluble basic zinc arsenate. Kadow and Anderson (8) intimate that the reaction of zinc sulfate in the spray solution may perform a dual function by preventing rapid carbonation of lime and by precipitating water-soluble arsenic as zinc arsenate whenever it is formed. They report excellent control of arsenical injury by using zinc sulfate.

The studies on effects of zinc sulfate-lime with arsenical sprays on the peach in the sandhill area during the past five years have shown that zinc sulfate affects practical control of arsenical injury. It was shown that it does not give absolute control, since in wet seasons some injury occurred even when zinc sulfate at the rates of 10 and 15 pounds was used in 50 gallons of spray. In these tests where zinc sulfate at the rates of 1.5, 2, 3, 4, 10, and 15 pounds in 50 gallons of spray solution was used, the injury was slightly less where the larger amounts were used although 3 and 4 pounds effected practical control and as little as one pound greatly reduced the injury. It was clearly shown that the leaves remained more tenaciously on trees sprayed with the zinc sulfate added to the solution. Growth of twigs continued normally as compared with arsenical sprays used without zinc sulfate. In some tests fused bentonite sulfur, flotation sulfur and sulfur dusts gave some reduction in injury. However, they have not given consistently good reductions. And injury has been severe irrespective of the type of sulfur used. Amounts of sulfur up to 10 and 15 pounds in 50 gallons of water were used, although the larger amounts did not increase the control values. During the extremely favorable season for arsenical injury in 1934, there was much less arsenical injury on trees sprayed with fused bentonite sulfur known as "Kolofof" used at the rate of 3 and 5 pounds to 50 gallons of spray than when used at the rate of one and two pounds. This material was used because it has the best adhesive characters of any substance found so far. Its permanent sticking qualities are recognized as of considerable importance as a retainer for the zinc sulfate-lime sprays also. During the past two seasons tests in which zinc sulfate was used in sprays applied after the buds had swollen and foliage had developed gave conclusive evidence of the value of zinc sulfate as a practical control of arsenical injury. The trees sprayed with 4 pounds of zinc sulfate, 5 pounds of chemical hydrated lime and one pound of arsenate of lead held the foliage throughout the season (Fig. 4). Those sprayed with the 5 pounds of chemical hydrated lime and one pound of arsenate of lead caused from 50 to 75 per cent defoliation on trees in rows adjacent to those sprayed with the mixture containing zinc sulfate (Fig. 5).

Additional applications of 10 pounds of lime in 50 gallons of water after arsenical injury was first observed affected slight reduction of arsenical



FIG. 5. Tree sprayed throughout season with 5 pounds of lime and one pound of arsenate of lead in 50 gallons of water, showing heavy defoliation cankers and much roughened bark around the crotches.

injury, but failed to give satisfactory control. Applying the zinc sulfate with arsenate of lead after two previous applications of arsenate of lead and lime on the new foliage gave specific reduction of fruit and leaf injury, but it was shown to be less effective than when zinc sulfate was used in all sprays after the buds had opened. These tests indicated that the addition of zinc sulfate to the early sprays is of greatest importance, and should be used in all sprays where arsenate of lead is used.

SUMMARY

Arsenical injury of the peach sometimes causes losses ranging from 5 to 35 per cent of the crop.

It affects leaves, twigs and fruit; causing brown spots, shot holes, defoliation, destruction of buds and twigs, cankers, and necrotic areas on the fruit and gum excretions on both twig and fruit.

The foliage, buds and twigs of Early Rose, Red Bird, Hiley Belle, and Georgia Belle, were injured severely in early sprays. Fruit injury was severe on Elberta, Hale, and Augbert varieties.

Injury was most prominent on leaf, twig, and bud on vigorous trees and on fruit on weakened trees.

The injury in the field is much worse under humid than dry conditions. The temperature is of minor or no significance.

Arsenate of lead from various sources regardless of the source caused severe injury when used alone and with lime.

Coarse limes were not as effective in reducing arsenical injury as chemical hydrated limes. Injury was less prominent as the amounts of lime were increased above 5 pounds.

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Zinc sulfate at the rates of 3 and 4 pounds with 5 pounds of lime and with one pound of arsenate of lead applied in all sprays after the leaves appeared resulted in significant control of arsenical injury on all varieties under optimum conditions for the development of arsenical injury. Sulfur in various forms was also added to this mixture and applied successfully.

BIBLIOGRAPHY

1. Bennett, C. W. Arsenical Injury to Peach. Mich. Agr. Exp. Station Quarterly Bul., Vol. 8, No. 4, May, 1926. *475*
2. Denson, L. A. Climatological Data. U. S. Dept. Agr., Vols. 37, 38, and 39, Nos. 4, 5, 6, 7, 8, 9, 1932, 1933, 1934.
3. Fernold, H. T., and A. T. Bourne. Injury to foliage by arsenical sprays. I. The lead arsenates. Mass. Agr. Exp. Sta. Bul. 207, 19 p., 23 figs. 1922.
4. Ginsburg, Joseph M. The effect of different soaps on lead arsenate in spray mixtures. Jour. Agr. Res., Vol. 46, No. 2, pp. 179-182; 1933. *XXI 256*
5. Haenseler, C. M., and Wm. H. Martin. Arsenical injury of the peach. Phytopathology, Vol. 15, No. 6, pp. 321-331; 1925. *XV 83*
6. Haywood, J. K., and C. C. McDonnell. Lead arsenate. U. S. Dept. Agr. Bur. Chem. Bul. 131, p. 46; 1910.
7. Hurt, R. H. Prevention of arsenical injury to peach twigs and foliage in Virginia. Phytopathology, Vol. 21, No. 12, p. 1204.
8. Kadow, K. J., and H. W. Anderson. The value of zinc sulfate as a spray ingredient. Phytopathology, Vol. 25, No. 1, p. 22.
9. McDonnell, C. C., and C. M. Smith. The preparation and properties of Lead-Chlor Arsenate, artificial mimetite. Amer. Jour. Science, Vol. 42, pp. 139-145, 2 fig.; 1916.
10. Mogendorff, N. Some chemical factors involved in arsenical injury of fruit trees. N. J. Sta. Bul. 419, pp. 3-47, fig. 5; 1925. *XIV 576*
11. Patten, Andrew J., and P. O'Meara. The probable cause of injury reported from the use of calcium and magnesium arsenates. Mich. Agr. Exp. Sta. Quart. Bul., Vol. 2, pp. 83-84; 1919.
12. Poole, R. F. Arsenical injury of the peach and some results of studies on its control. Proceedings American Society for Horticultural Science, Vol. 29, pp. 42-44; 1932. *XXII 32*
13. Poole, R. F. Wind and sand injury to leaves and fruits. Jour. Elisha Mitchell Sci. Society, Vol. 49, No. 1, pp. 171-175. Sept. 1933.
14. Roberts, J. W., and L. Pierce. Zinc Lime: A Fungicide for the Peach. Phytopathology, Vol. 22, 5, pp. 415-427; 1932.
15. Smith, C. M. Excretions from leaves as a factor in arsenical injury to plants. Jour. Agr. Res., Vol. 26, No. 4, pp. 191-194; 1923. *XII 119*
16. Snapp, Oliver T. Experiments on the control of the plum curculio, brown rot and scab, attacking the peach in Georgia. U. S. D. A. Department Bul., No. 1482, April, 1927.
17. Swingle, D. B., and H. E. Morris. Injury to foliage by arsenical spray mixture. Jour. Agr. Res., Vol. 24, No. 6, pp. 501-537; 1923. *XI 522*
18. Woodworth, C. W., and George E. Colby. Paris green for the Codling-Moth. Calif. Agr. Exp. Sta. Bul. 126, 40 p. Illus.; 1899.

